ENGINEER RESEARCH & DEVELOPMENT CENTER
Topographic Engineering Center

Impact of Shuttle Radar Topography Mission (SRTM) Data on Geospatial Support to U.S. Army Operations

Outline

- Background
- Study Objectives
- Primary Study Analyses
- Study Findings
- BOTTOM LINE
- Follow-On Work

  - Vegetation and Noise Reduction Analyses

Background

- February 2000: SRTM elevation data 30 meter resolution (SRTM DTED Level 2 [SRTM2]) collected over 80% of the earth's surface (60° N to 56° S).
- SRTM2 comprises the bulk of the National Geospatial Intelligence Agency's (NGA) elevation data holdings and is a critical "backbone" mapping resource.
- Army prepared a proposal to conduct a ground-truth validation of SRTM2 data to determine operational effectiveness.
- DCS/G2 provided FY04 funding through Army Study Program.
- Study Analyses, Conclusions, Recommendations were completed March 2005

Study Objectives*

- **Determine comparative utility of SRTM2 versus existing traditional products of a similar resolution, e.g., Digital Terrain Elevation Data Level 2 (DTED2) and 1:50,000 scale Topographic Line Map (TLM) in an operational setting**

- **Provide guidelines for Army's use of SRTM2 data in applications requiring elevation data.**

*Bare earth evaluation only. Determination of SRTM performance in forested areas is contained in a follow-on report; publication date: July 05

Primary Study Analyses

Operational

- LINE-OF-SIGHT (LOS) PREDICTION
- CONTOUR GENERATION
- SLOPE DETERMINATION

Other

- TERRAIN PROFILE ANALYSIS
- VOID/VOID FILL ANALYSIS
- RESIDUAL RADAR NOISE

Study Findings

Positional Accuracy

Accuracies	*SRTM 1 and 2*	*DTED 1*	*DTED 2*
Absolute Horizontal	20	50	23
Relative Horizontal	NA	NA	NA
Absolute Vertical	16	30	18
Relative Vertical	10	20	12-15

Current and previous studies have validated SRTM positional accuracy is well within stated specification

- Consistent improvement over DTED (all cells)

General

+ **Homogeneous/Increased Coverage**

  - 60 degrees North to 56 degrees South Latitude; especially valuable in perpetually cloud-covered areas along the equator and in other locations where elevation data had previously been unavailable.

  - Consistent Characteristics, i.e., same “look and feel”; improvement over DTED2

+ **Improved Terrain Visualization** – SRTM2 can be used in conjunction with Controlled Image Base (CIB) to provide better visualization of the terrain and its impact on military operations.

+ **Better Support to Orthophoto Rectification** – NGA is currently using SRTM2 data to orthorectify CIB 1 & 5 on a routine basis with excellent results.

- **Radar Specific Anomalies, e.g., Data Voids and Residual Noise, can offset SRTM2 advantages especially in very smooth terrain areas.**

LOS Prediction/Contour Generation

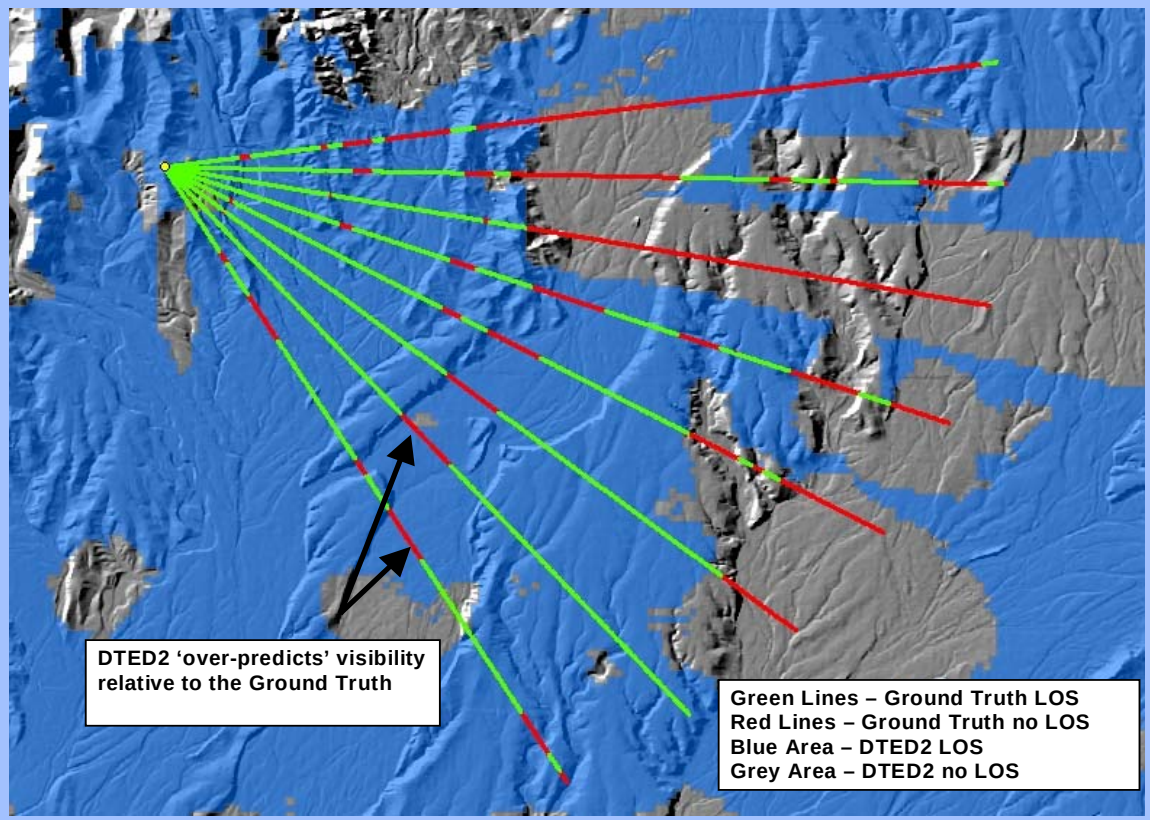
Conclusions

+ Typical LOS agreement vs. ground truth is much improved using SRTM2 vs. DTED1 (~80% vs. ~55%); slightly better than DTED2 - in most areas.
- In very smooth terrain, LOS prediction accuracy is degraded (consistent underprediction of LOS) due to residual noise in the SRTM2 data.

+ Contours generated from SRTM2 will perform as well as or better than those generated from DTED2 in all but the smoothest terrain.
- Radar noise will have a serious negative impact on 1:50K contour generation in very smooth areas, often resulting in a confusing depiction of the terrain surface.

LOS Prediction

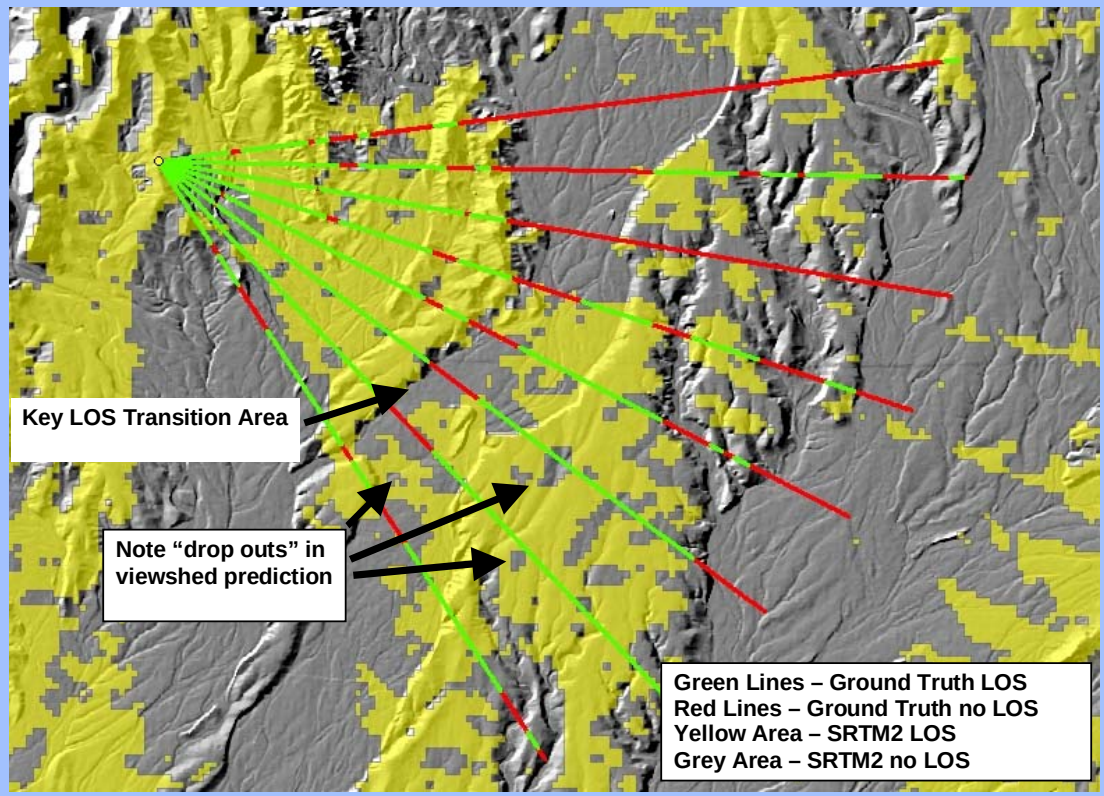
Comparison of Ground Truth Azimuths to DTED2 Viewshed Plotted over a 5m Reference DEM



DTED2 overpredicts LOS relative to ground truth

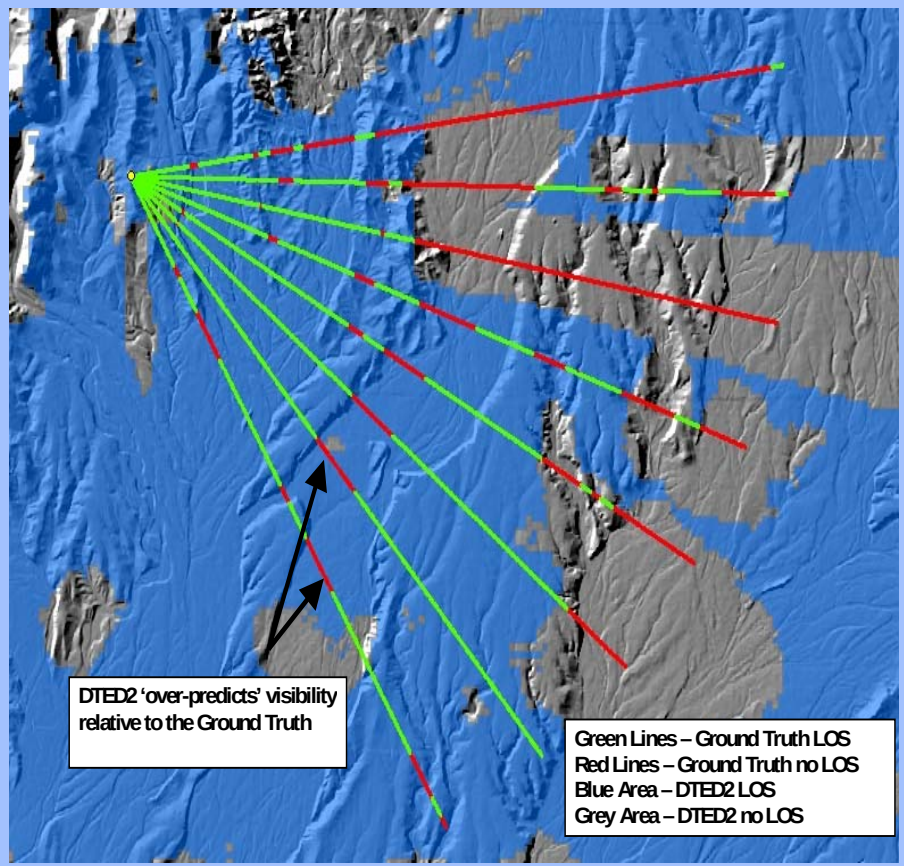
LOS Prediction

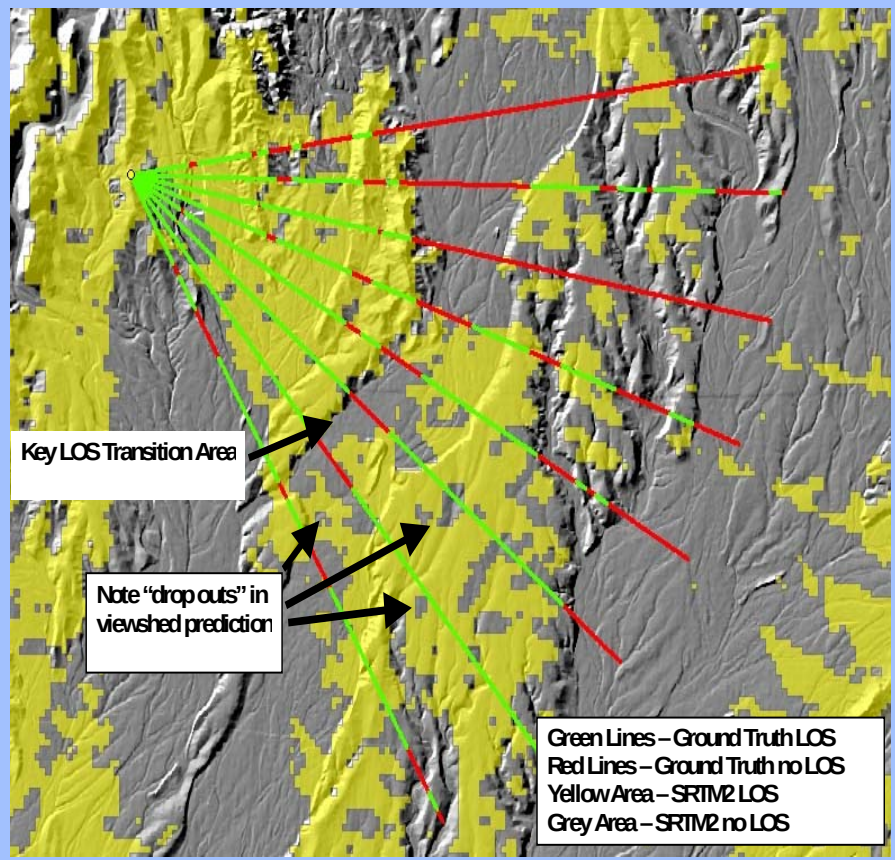
Comparison of Ground Truth Azimuths to SRTM2 Viewshed Plotted over a 5m Reference DEM



SRTM2 better matches ground truth despite residual noise

LOS Prediction

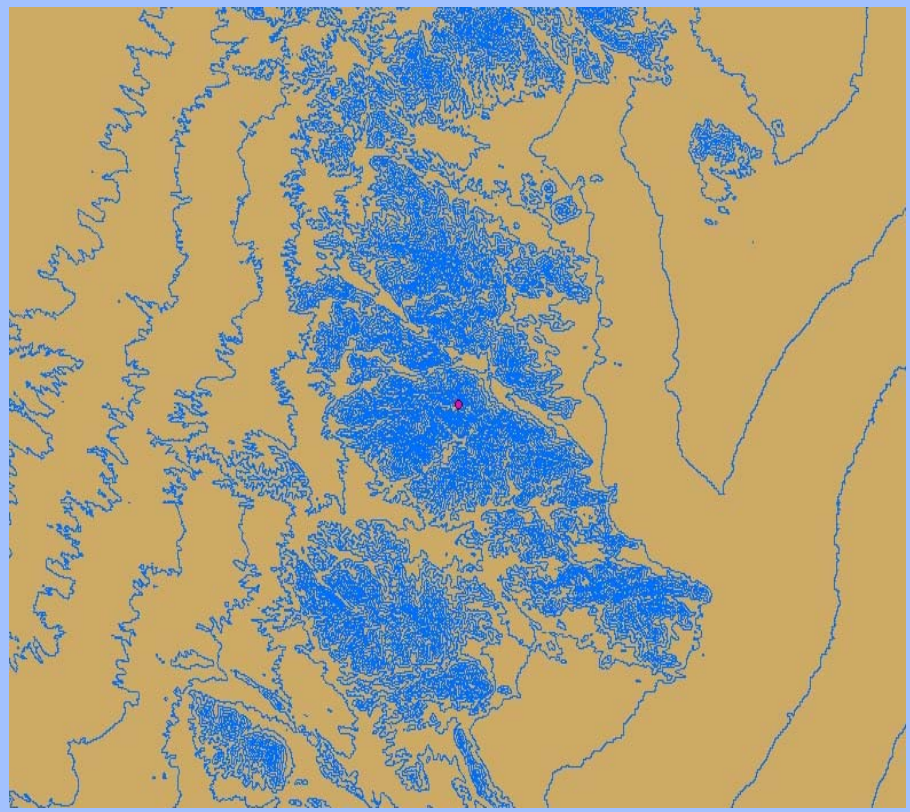




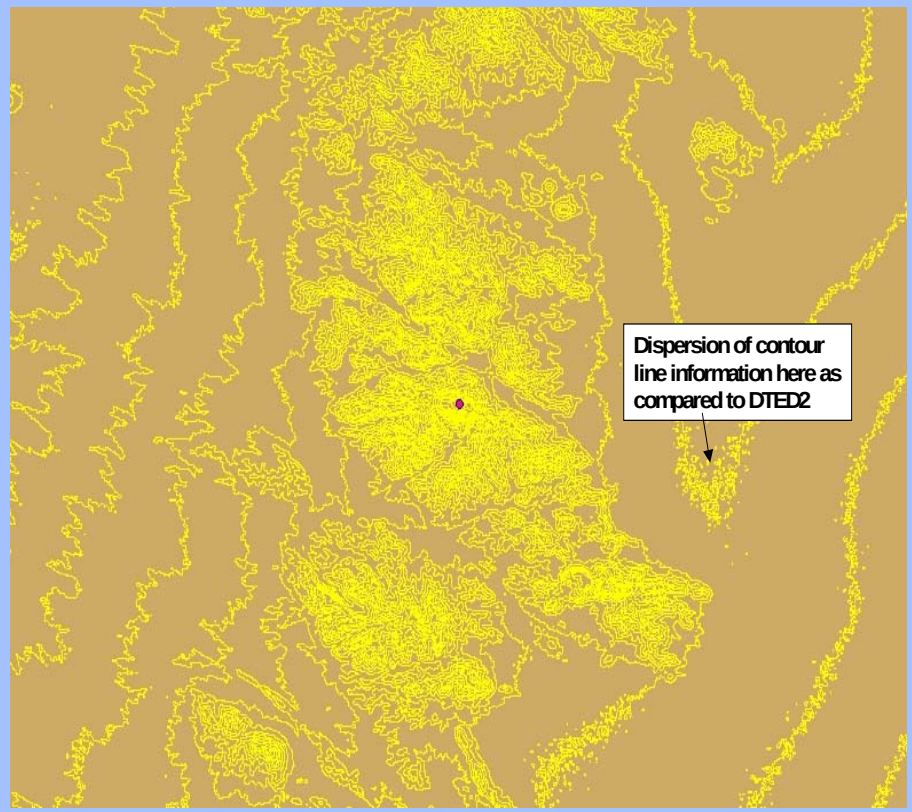
DTED2 vs. SRTM LOS Comparison

Contour Generation

40-meter Contours from DTED2 @ YPG



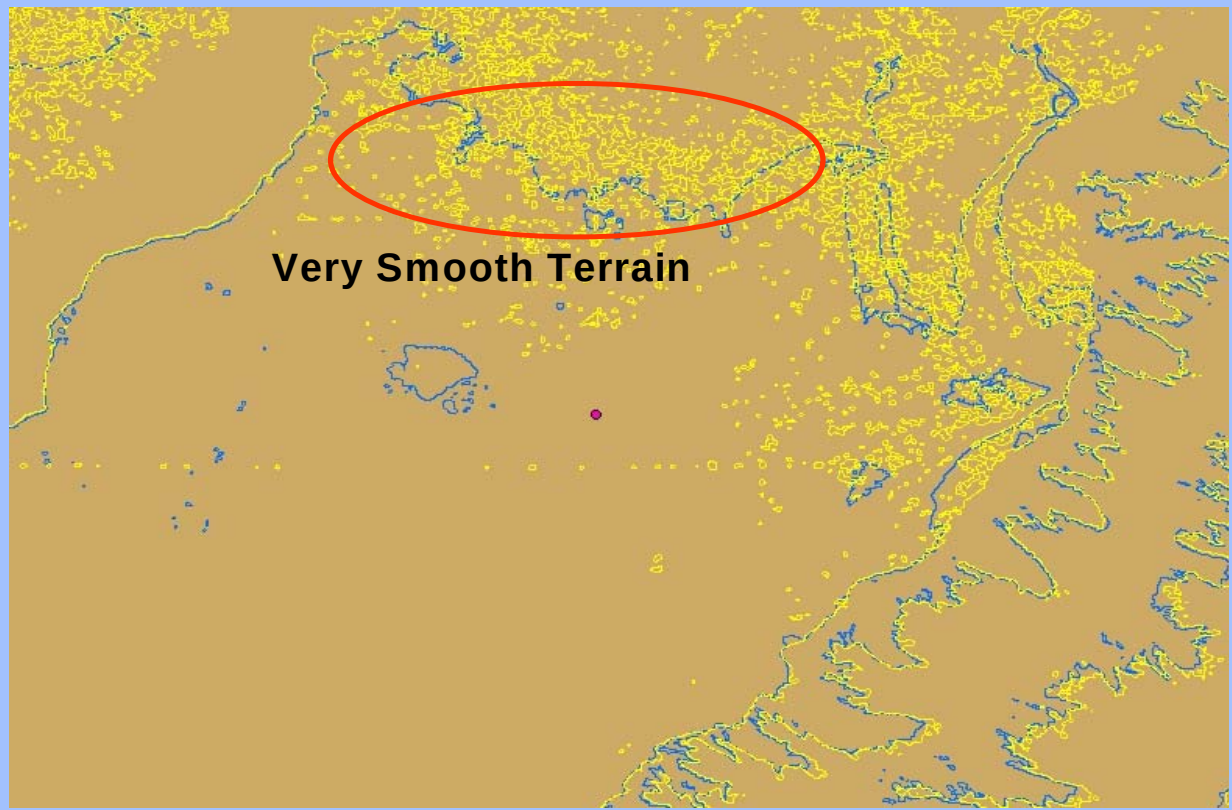
40-meter Contours from SRTM2 @ YPG



Dispersion of contour information generated from SRTM2 results in confusing depiction of terrain

Contour Generation

40-Meter Contours Developed from SRTM2 and DTED2 at Blythe, CA



SRTM2 contour information is meaningless in very smooth terrain

LOS Prediction/Contour Generation

Recommendations

- Exercise caution when applying SRTM2 derived LOS prediction results to mission applications in very smooth terrain.
- Validate results when feasible through comparison to other available sources such as large scale topographic line maps or request trustworthy alternative elevation data sources.
- SRTM2 derived contours should not be used for applications in areas with minimal elevation changes, e.g., <1 contour interval per km @ 1:50K scale.
- NGA investigations regarding more effective noise removal algorithms should be expanded to improve SRTM2 utility for contour generation in smooth terrain.

Slope Generation/Terrain Profile Analysis

Conclusions

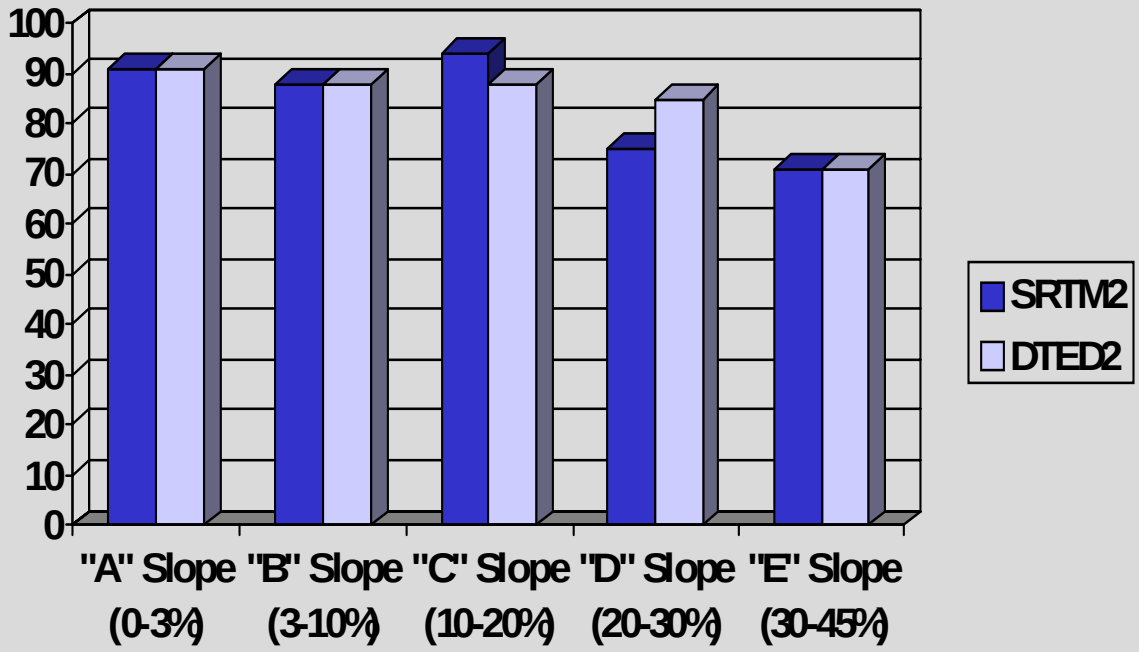
+ SRTM2 data was highly correlated (88 percent) to ground truth for all five major military slope classes and will fully support normal operational applications requiring a slope calculation.

0 The primary error observed between the SRTM2 predictions and the field results is underestimation of steeper slope classes (upper “C”- “E”); typically not the most critical areas from an operational standpoint.

+ When compared to ground-truth terrain profiles, SRTM2 data provides equal or better characterization of the terrain than DTED2 in most cases.

- Radar noise anomalies evident in terrain profiles over very smooth terrain areas remain an issue of concern

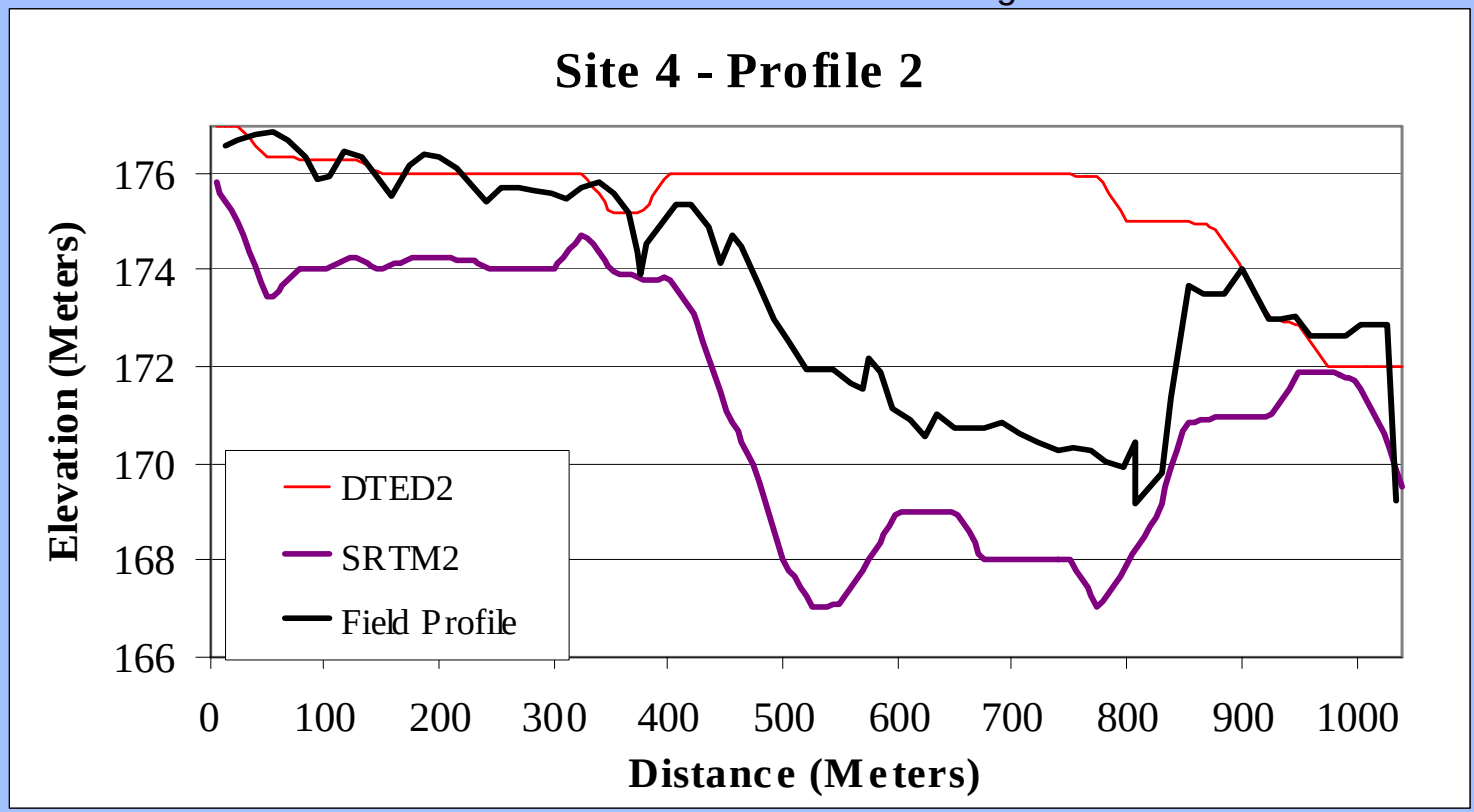
Slope Generation



Percent of correct slope predictions using SRTM 2 and DTED 2 versus Ground Truth at Yakima Training Center

Terrain Profile Analysis

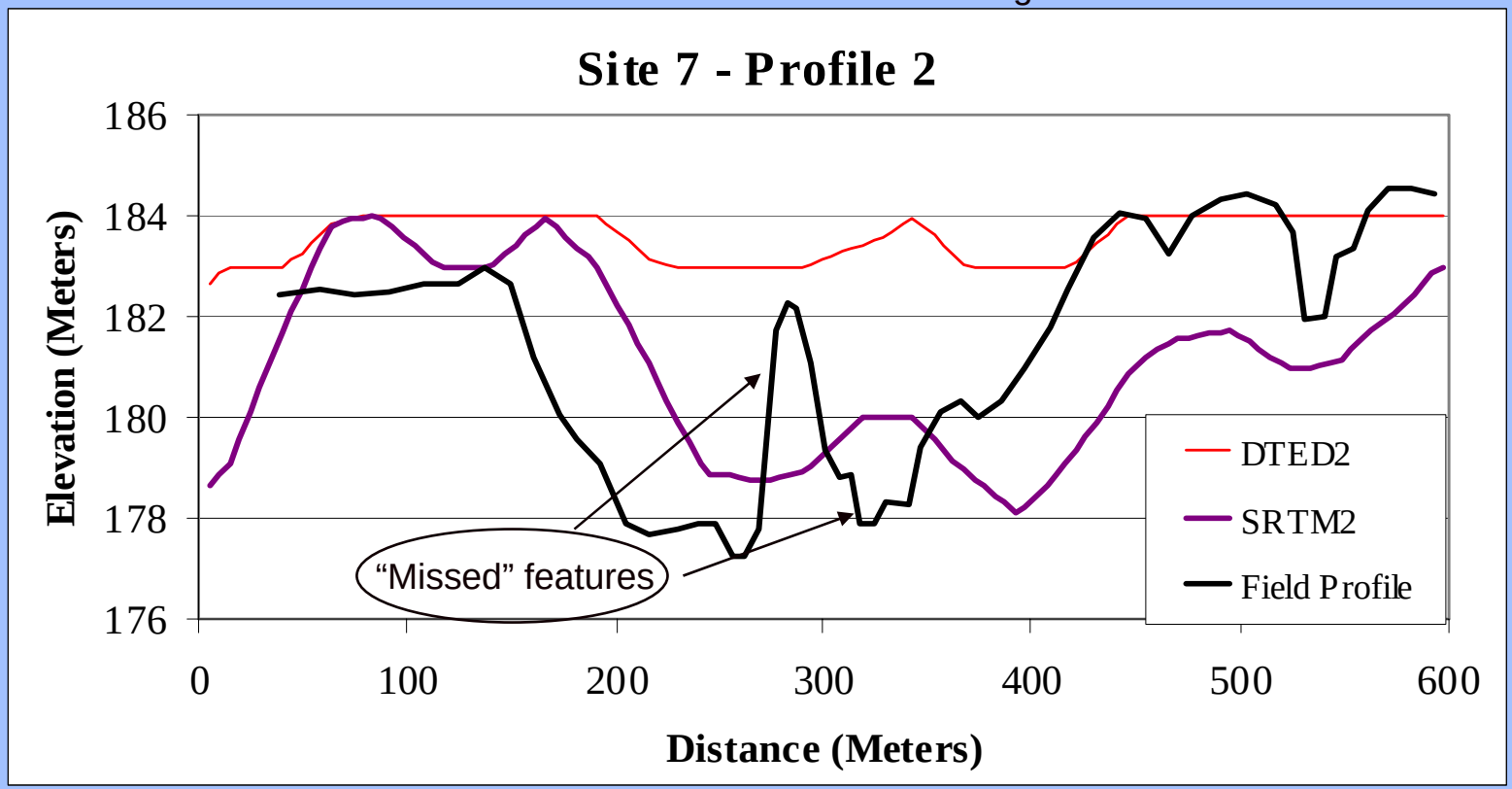
Field-Collected Profile Versus Profiles Generated Using SRTM2 and DTED2



SRTM2 has better correlation with ground truth than DTED2 -- But….

Terrain Profile Analysis

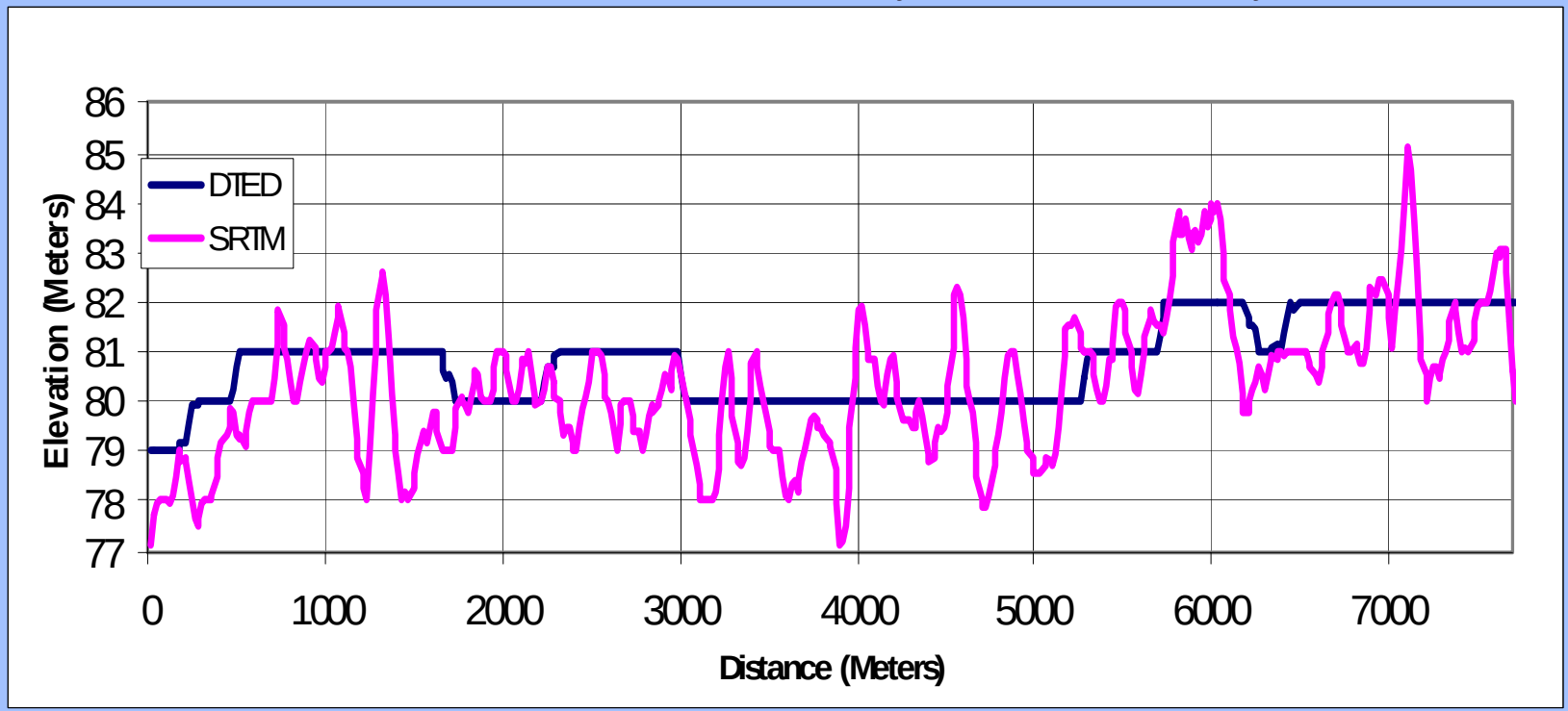
Field-Collected Profile Versus Profiles Generated Using SRTM2 and DTED2



…will still not depict smaller terrain features (<30m)

Terrain Profile Analysis

SRTM2 and DTED2 Terrain Profiles Over Very Smooth Terrain at Blythe, CA



SRTM2 exhibits significant residual noise in very smooth areas

Slope Generation

Recommendations

- SRTM2 data sufficiently predicts traditional military slope classes so that no specific guidelines are required, especially in the A and B slope classes (<10%).

- SRTM2 can also be used with confidence in military slope classes C through E (>10%) although lesser accuracy can be expected. Fortunately, these steeper classes tend to restrict maneuverability and therefore, are avoided when possible.

Void/Void Fill Analysis

Conclusions

0 SRTM2 distributed by NGA on DVD is non-void filled. This data is identified as “Edition 01” for 100% complete cells or “Edition 99” for partials.

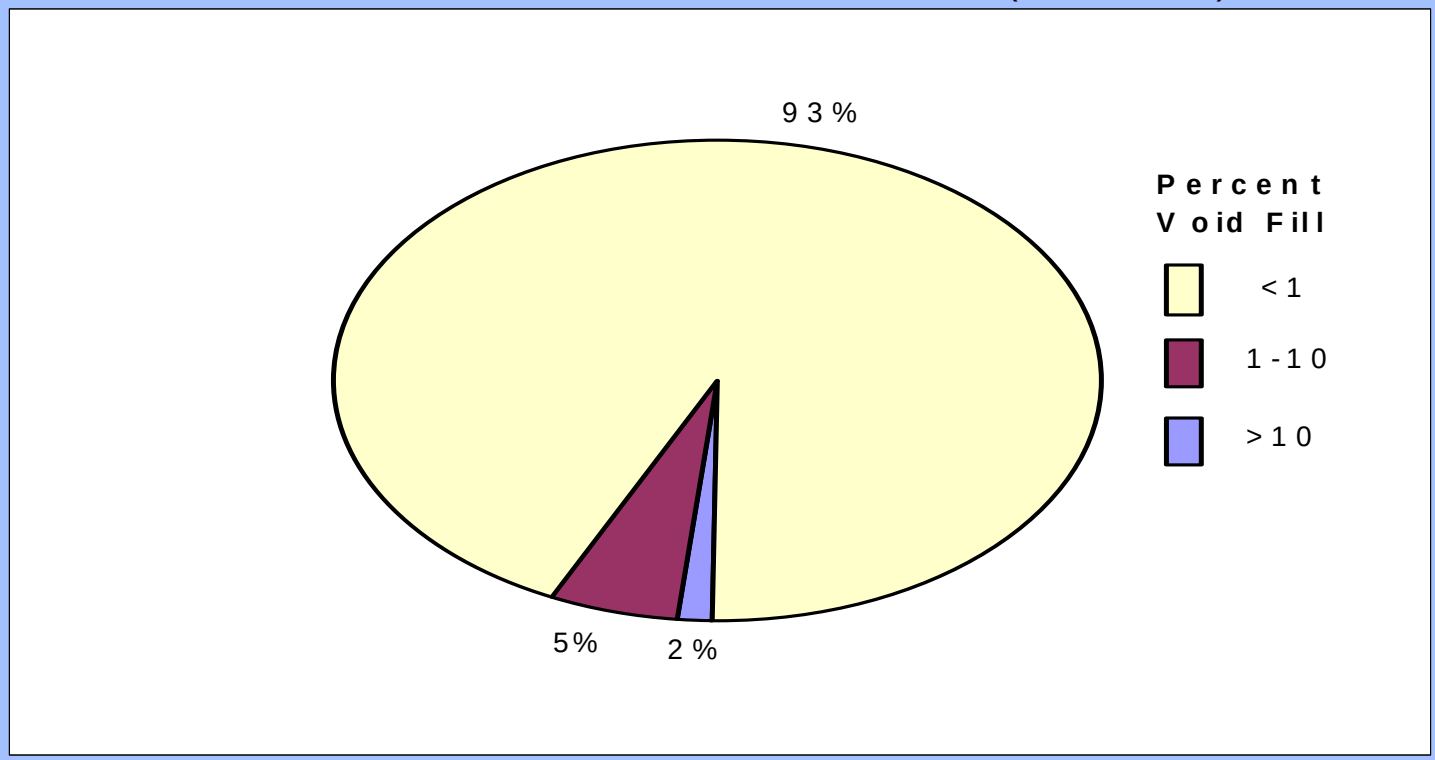
0 SRTM2 with void fill is available only on the NGA Gateway. Header information will contain source used (primarily DTED1).

+ Less than 10% of all SRTM2 voids are smaller than 16 post spacings. These voids are interpolated from existing data and will likely have little impact on the operational use of SRTM2 in Army applications.

- Anomalies within and adjacent to larger voids (resulting from weak radar signal and the use of DTED1 as fill source) will cause a serious negative impact on Army operational applications and users must exercise caution when using SRTM2 in these areas.

Void Fill Analysis

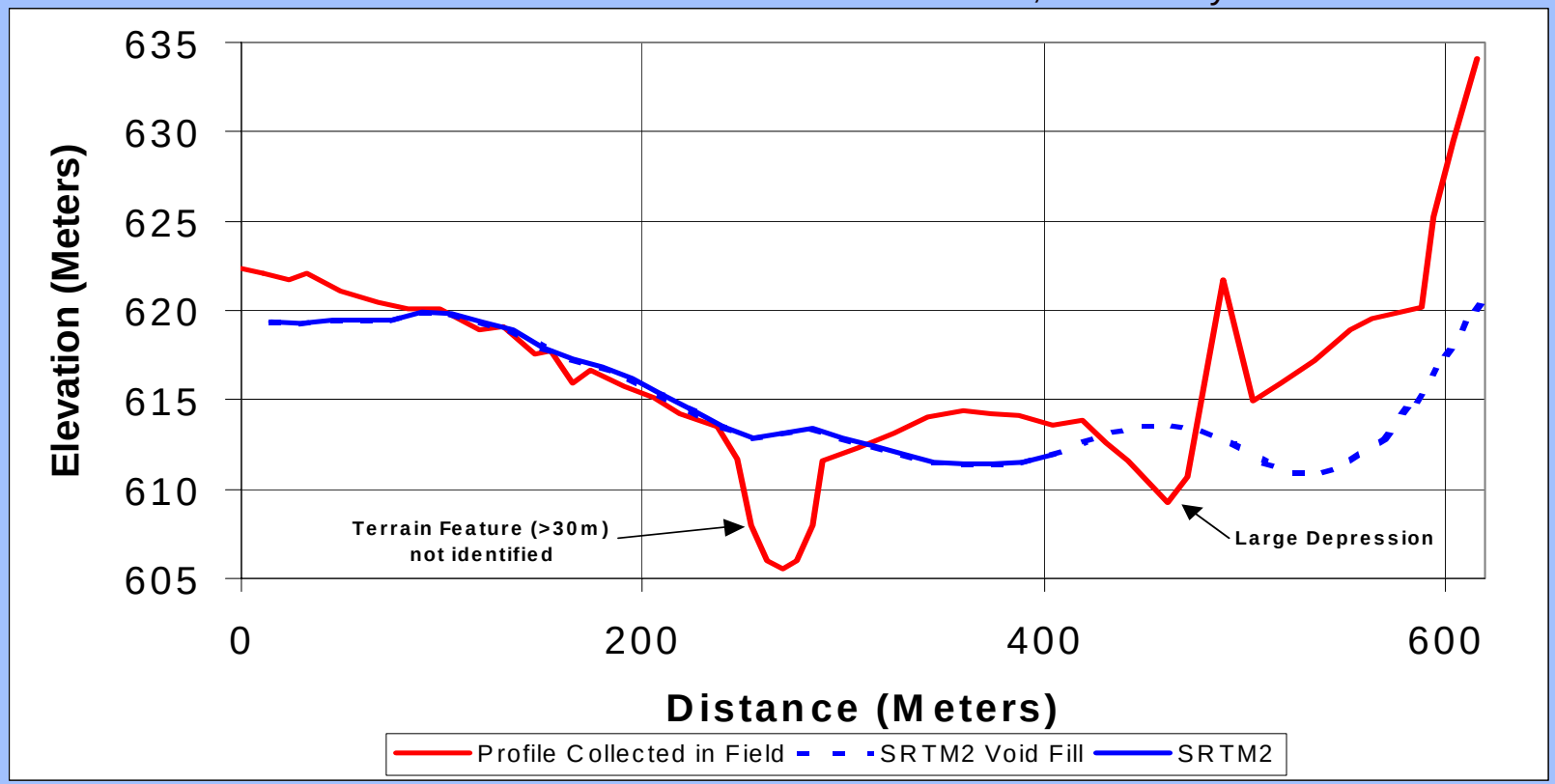
SRTM2 Void Fill in Relation to Total Production (14,277 cells)



93% of SRTM2 cells are over 99% complete

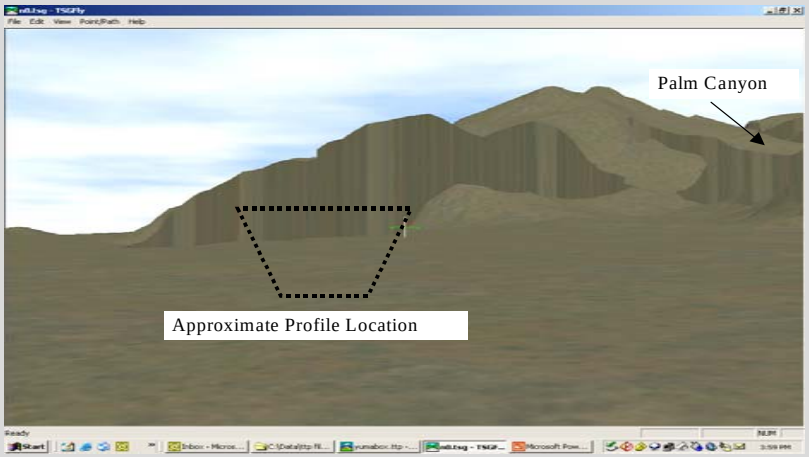
Void/Void Fill Analysis

SRTM2 Void Fill Area versus Ground Truth Profile, Palm Canyon AZ

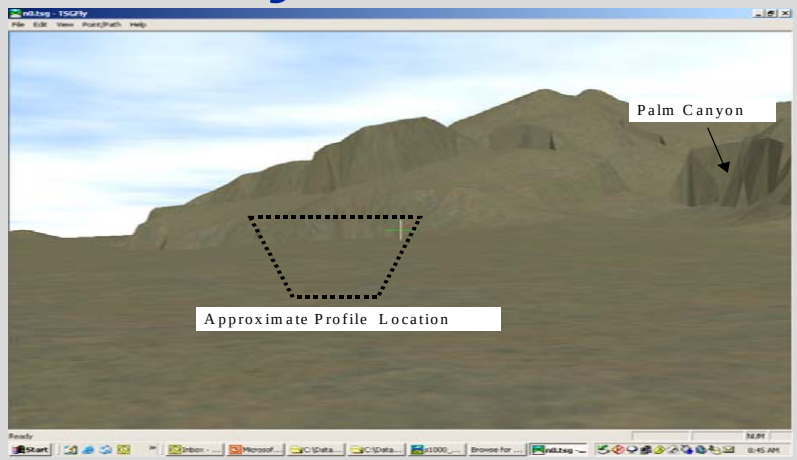


Fidelity of terrain representation is degraded in void fill areas (DTED1 source)

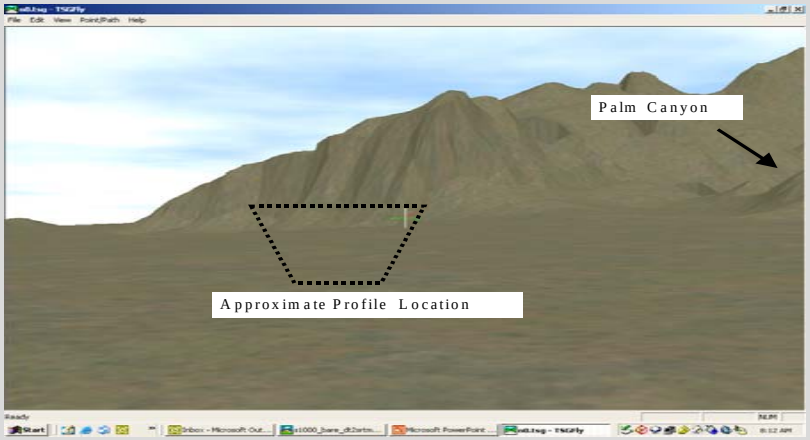
Void/Void Fill Analysis



No Void Fill



Void Filled with DTED1



Void Filled with DTED2

Ground Truth

Void/Void Fill Analysis

Recommendations

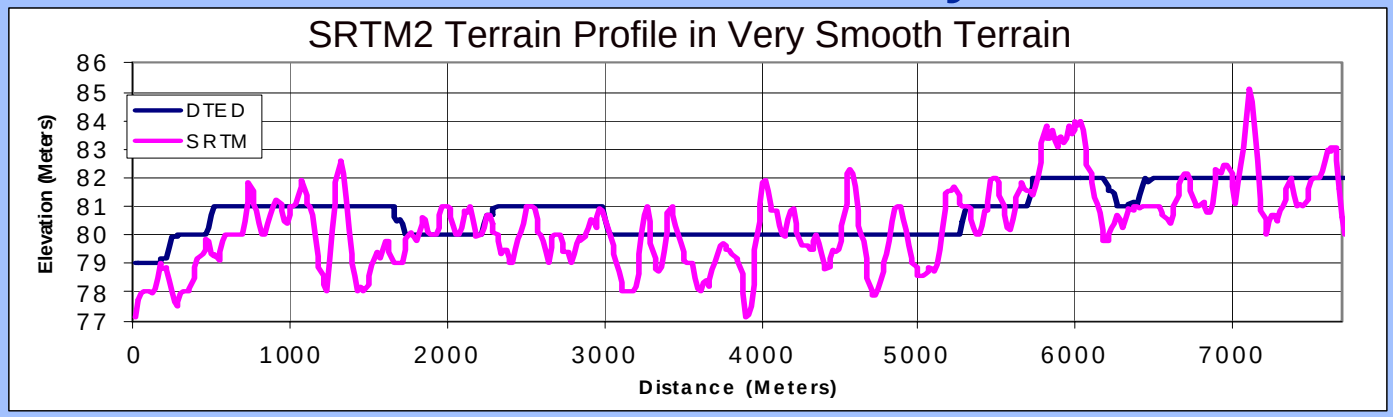
- Identification of all void/void fill areas within a specific area of interest should be a prime consideration for all users of SRTM2…BUT…No easy method available.
- NGA needs to identify void fill boundaries/percentages in each delivered SRTM2 cell metadata header – DOES NOT CURRENTLY EXIST!!
- Mapping applications must incorporate a means to alert users when unfilled SRTM2 voids are encountered.
- Larger void fill areas (over 16 pixels) should be avoided for operational applications and be viewed with caution for training applications due the lower resolution of the fill data.
- Users should consider an alternate elevation data source (e.g., digital elevation data derived from DPPDB, other radar, etc.) if an operation must be conducted over an area with extensive SRTM2 data voids/void fills.

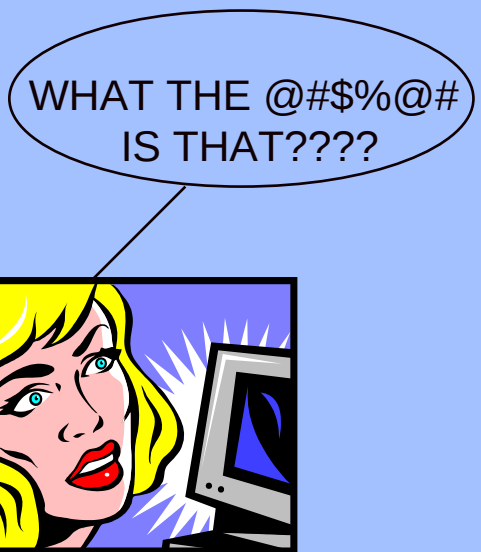
Residual Radar Noise

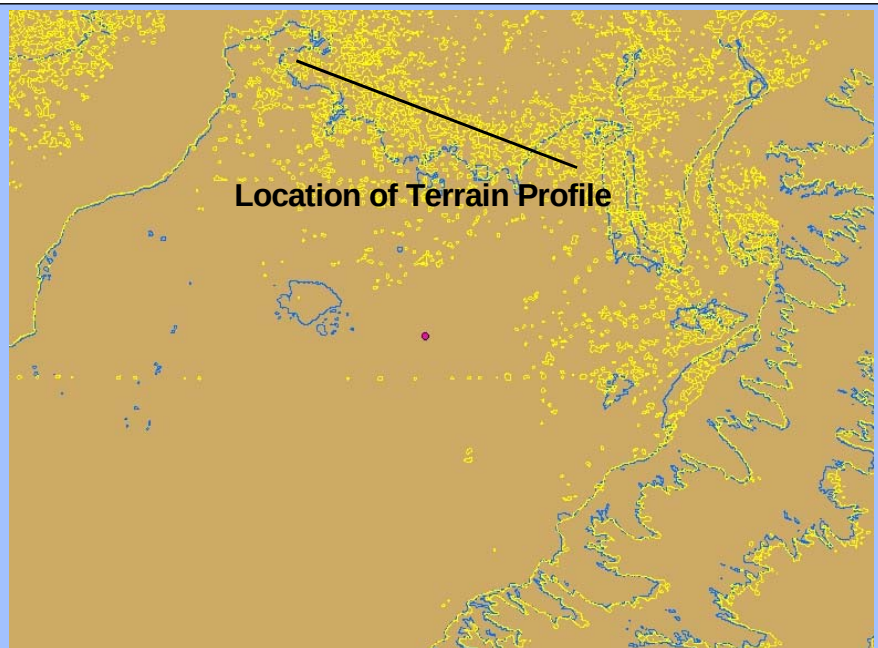
Conclusions

- “Random vertical noise” is inherent to all radar source data.
- All SRTM2 typically contains residual radar noise artifacts of 3-5m that are especially evident in “very smooth” terrain
- **+/-** NGA filters a portion of the noise but what remains has definite implications on use
  - TLM contour lines generated in smooth terrain are unusable due to random SRTM2 data noise that remains after final processing.
  - Noise-induced artifacts create erroneous results in LOS and related visualization applications in smooth terrain areas especially at the low grazing angles required for most Army operations.

Residual Noise Analysis



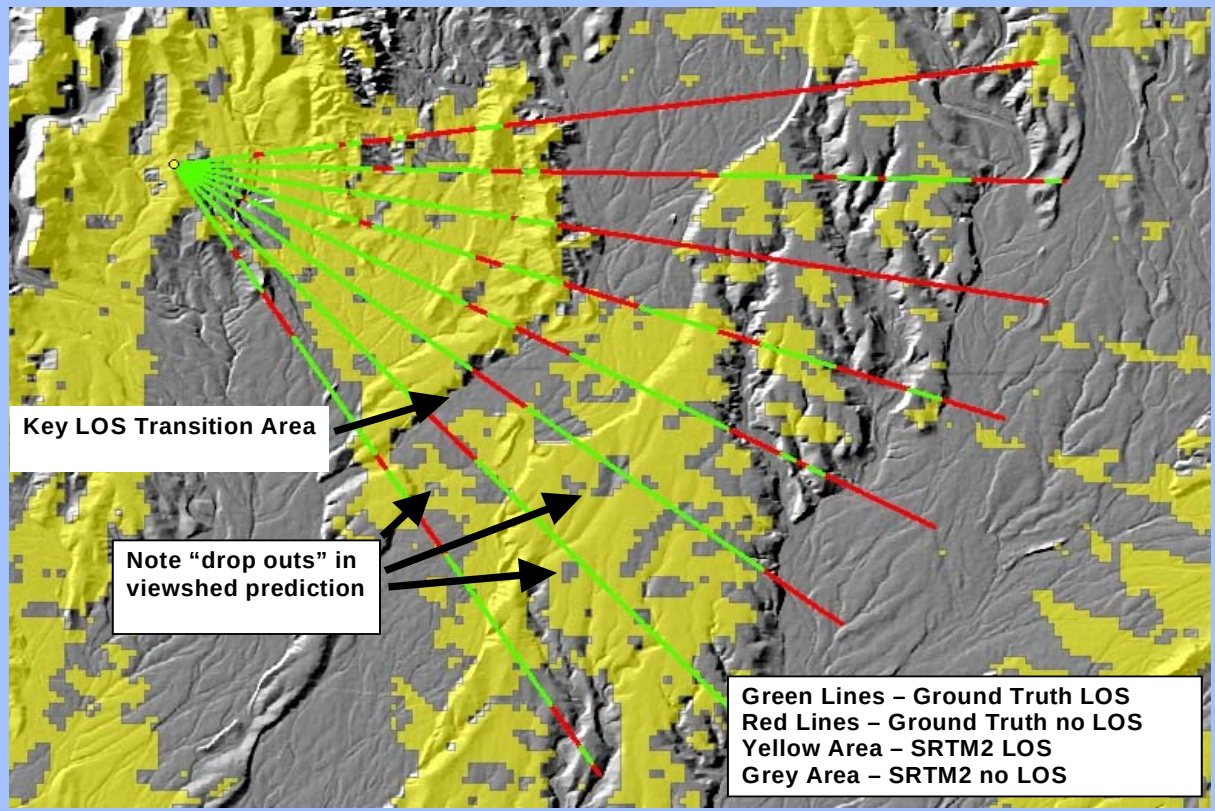




Unusable contour information caused by radar noise

Residual Noise Analysis

Comparison of Ground Truth Azimuths to SRTM2 Viewshed Plotted over a 5m Reference DEM



Radar noise-induced dropouts in LOS viewshed

Residual Radar Noise

Recommendation

- Users must apply caution when using SRTM2 data in very smooth terrain due to residual noise that negatively impacts all applications to some extent.

BOTTOM LINE

- **SRTM2 provides an excellent source of information regarding the configuration of the earth's surface that can be applied to a number of Army operations.**
- **SRTM2 contains artifacts from the shuttle radar collection and subsequent data finishing that affect its utility.**
- **In general, users must apply caution when using SRTM2 in very smooth terrain (due to residual noise) and in void/void fill areas**

Follow-On Work

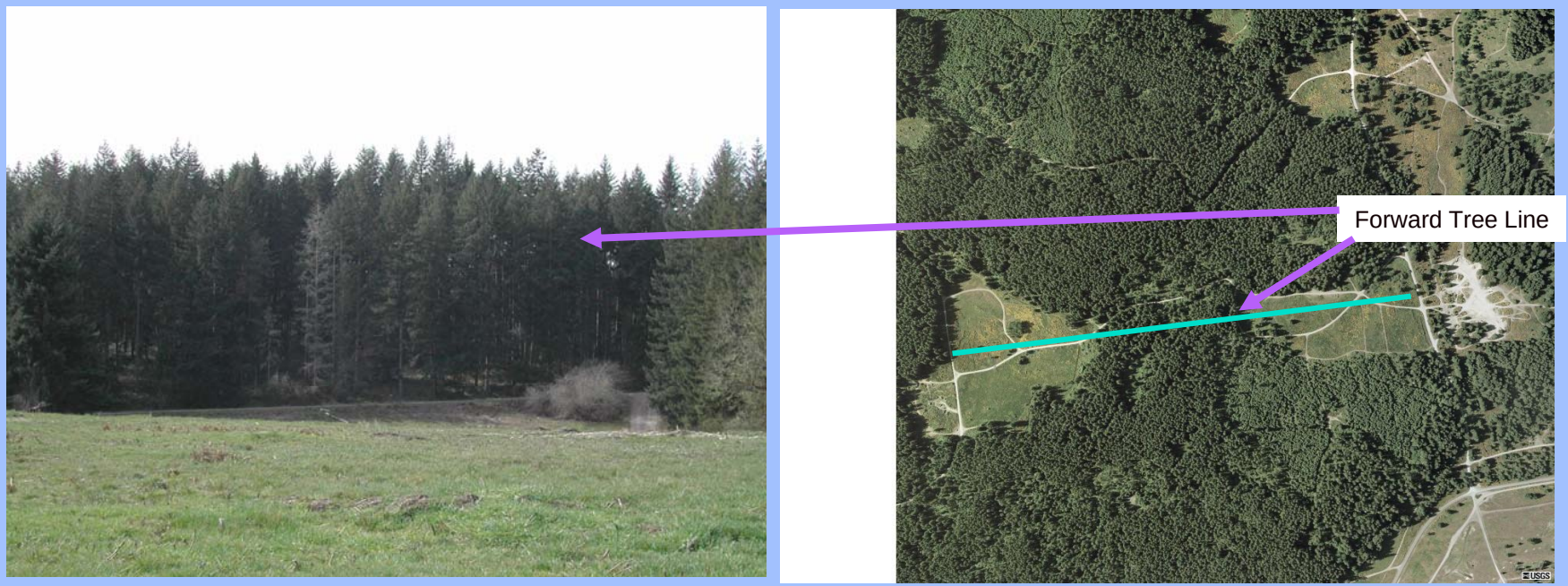
- **Congressional Add-on Funded Study to:**
  - Determine the accuracy of SRTM2 under vegetative canopy
  - Investigate methods for reducing SRTM2 residual radar noise
  - Determine SRTM2 utility in supporting aviation applications (not addressed in this briefing)
- **Preliminary Findings Completed**
- **Full Report will be Available in July 05 through ERDC-TEC**

Vegetation Analyses

Radar Penetration

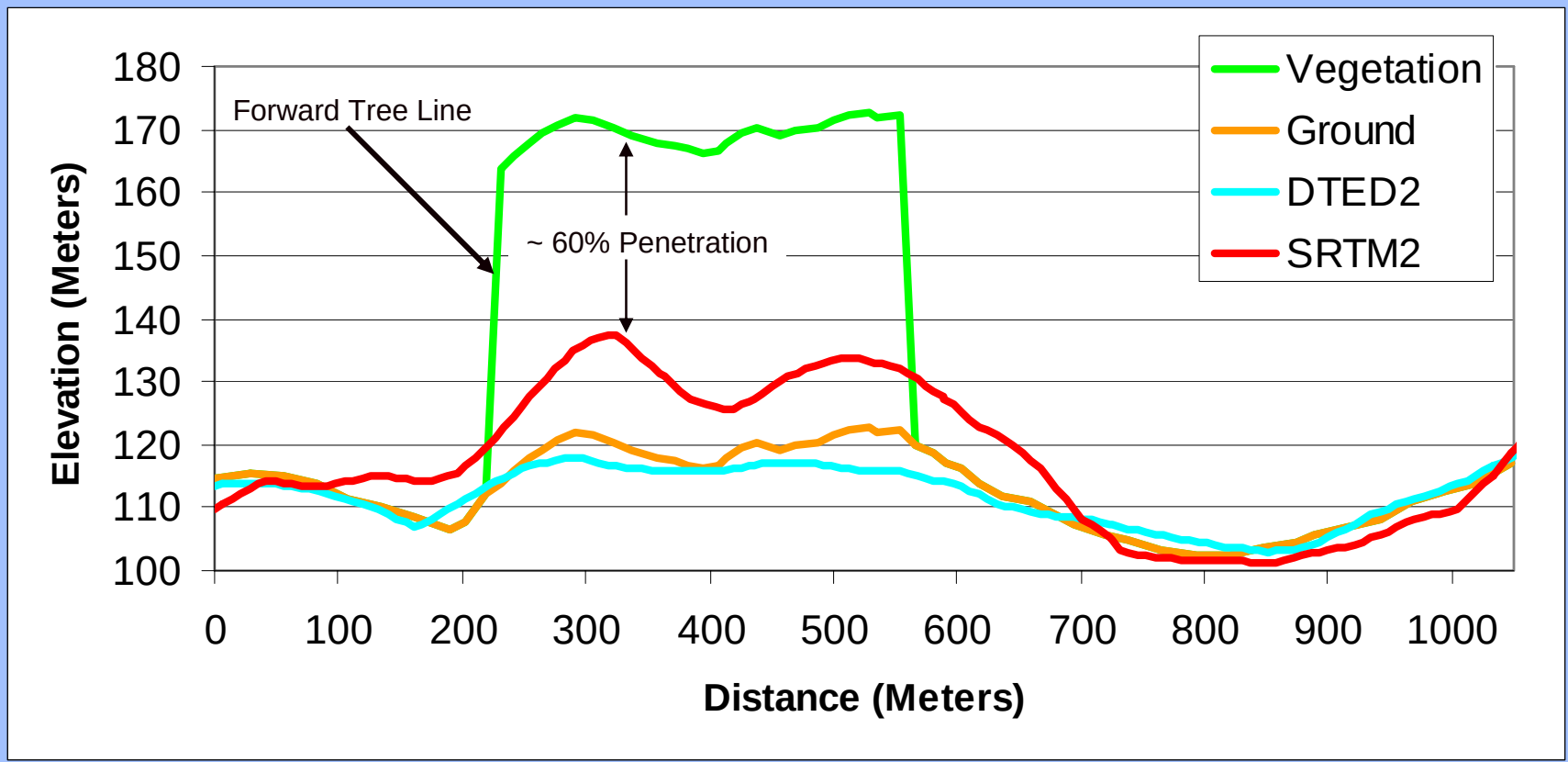
- Due to the February 2000 collection date of the SRTM2, the vegetative analyses were conducted solely in Northern Hemisphere coniferous forests (Ft. Lewis, WA and AFA, CO) to assure the evaluation of full foliage canopies.
- Dense to Medium Dense canopies (50-100% closure) at nine study sites were examined.
- No urban areas were evaluated

Vegetation Analysis



FT. Lewis Site 4: Tree Line and Approximate Profile Location

Vegetation Analysis



Ft. Lewis Area 4 Field Results

Vegetation Analysis

Conclusions

- On average, SRTM radar will penetrate canopies of medium to dense evergreen forests (50-100 percent canopy closure) to a level of between 50 and 60 percent of the predominant tree height.

- This characteristic of the SRTM data will impact applications expecting either the top of the vegetation canopy or the bare ground level as neither is well depicted.

Noise Reduction Analysis

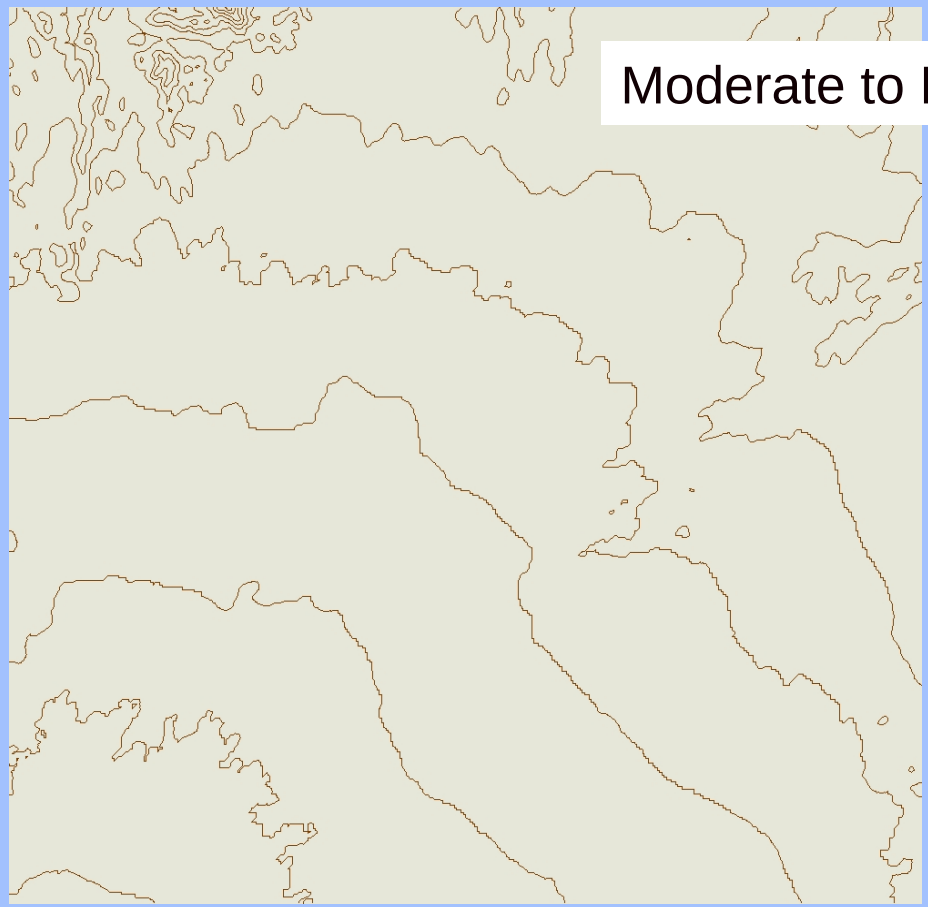
Support to Contour Generation

- Two 10x10 km areas were examined for contour analysis:
  - Moderate to Rough terrain at Yuma Proving Ground, AZ (YPG)
  - Very smooth terrain (<1 contour per km @1:50K scale) just south of Blythe, CA
- Various Filter/Pass Combination Used
  - Mean, Median, Gaussian
  - 1-100 passes
- Coincident terrain profiles generated to validate terrain fidelity after filtering

LOS Prediction

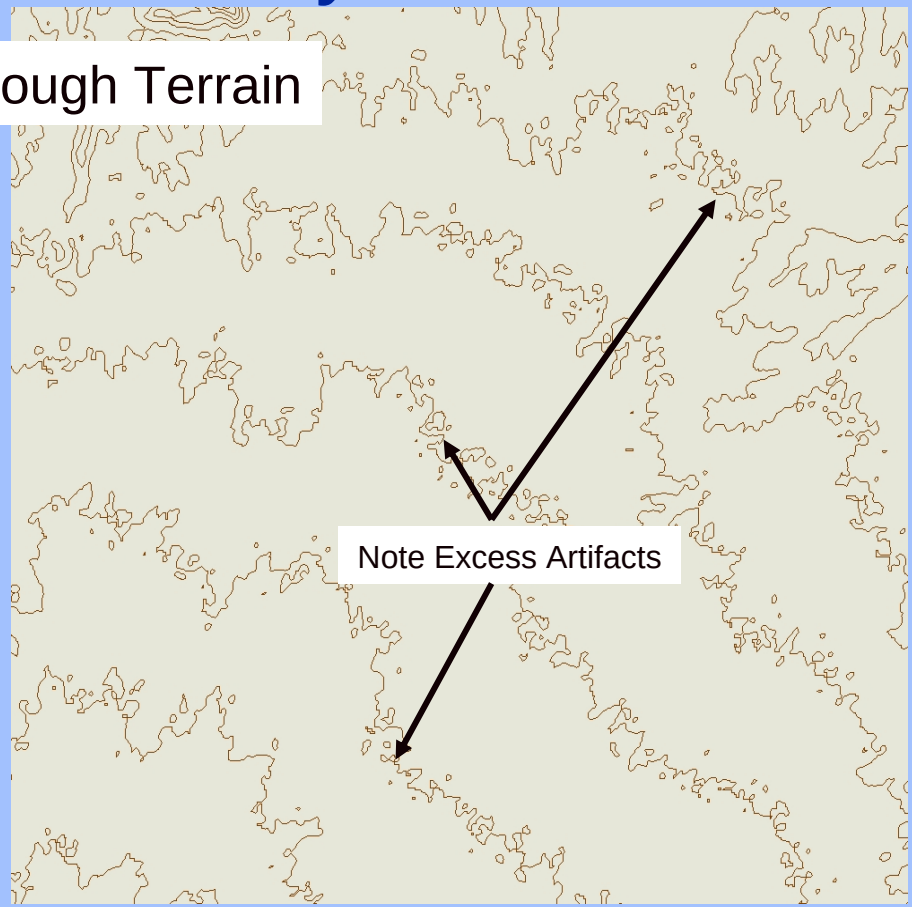
- Statistical comparison of field LOS versus computer generated LOS using various SRTM2 filter/pass combinations in moderate to rough terrain at YPG

Noise Reduction Analysis



Moderate to Rough Terrain

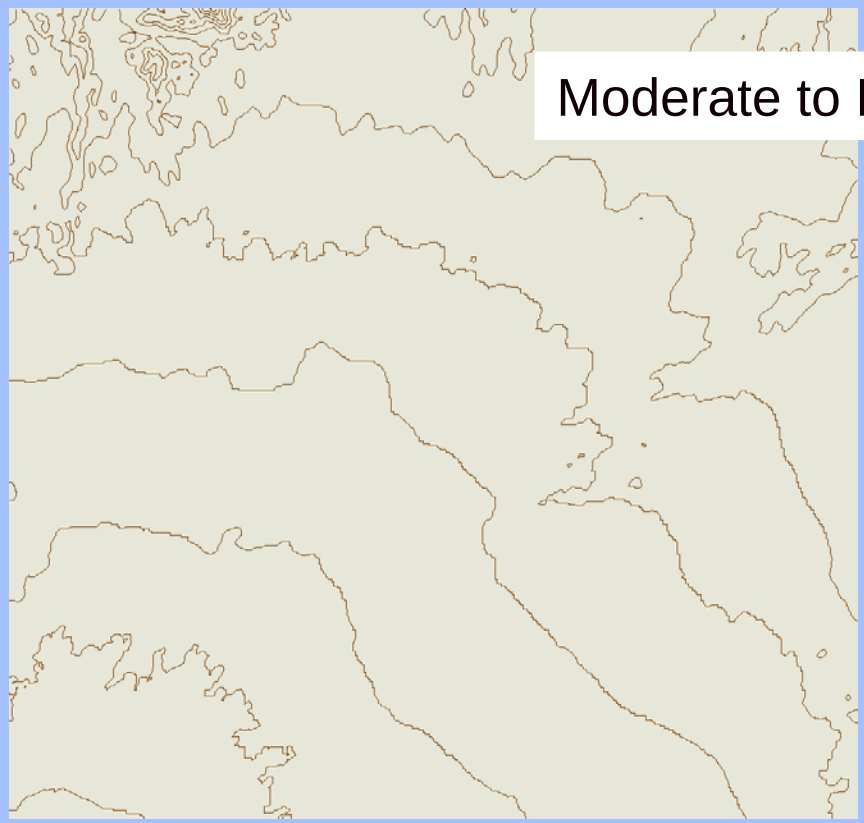
Yuma 20m Contours from DTED2



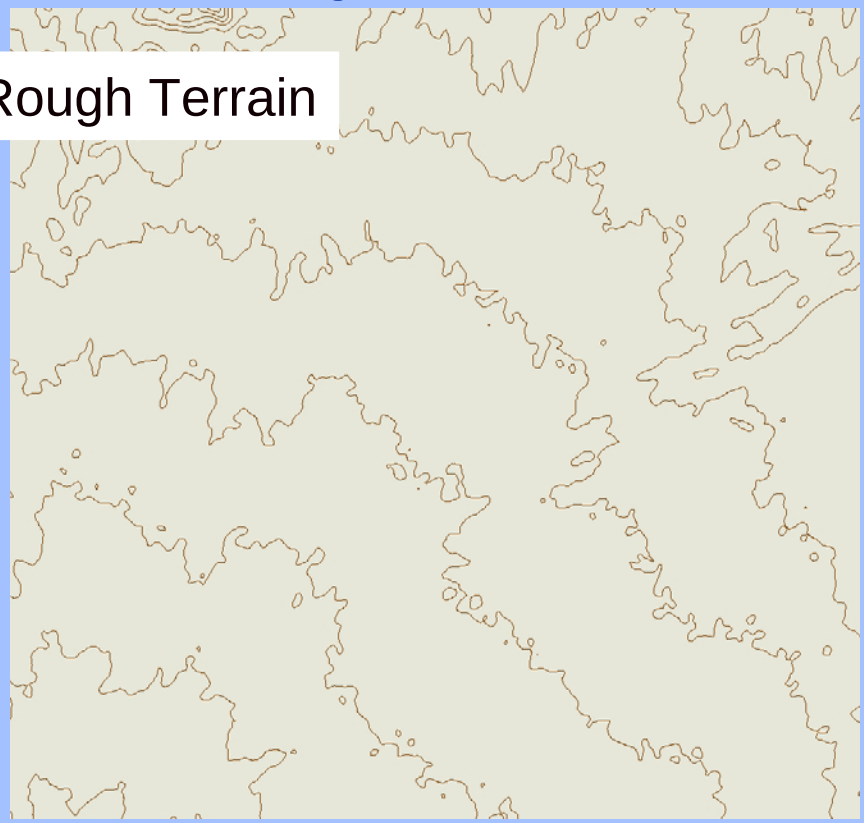
Yuma 20m Contours from SRTM2
(No Filter Applied)

Noise Reduction Analysis

Moderate to Rough Terrain



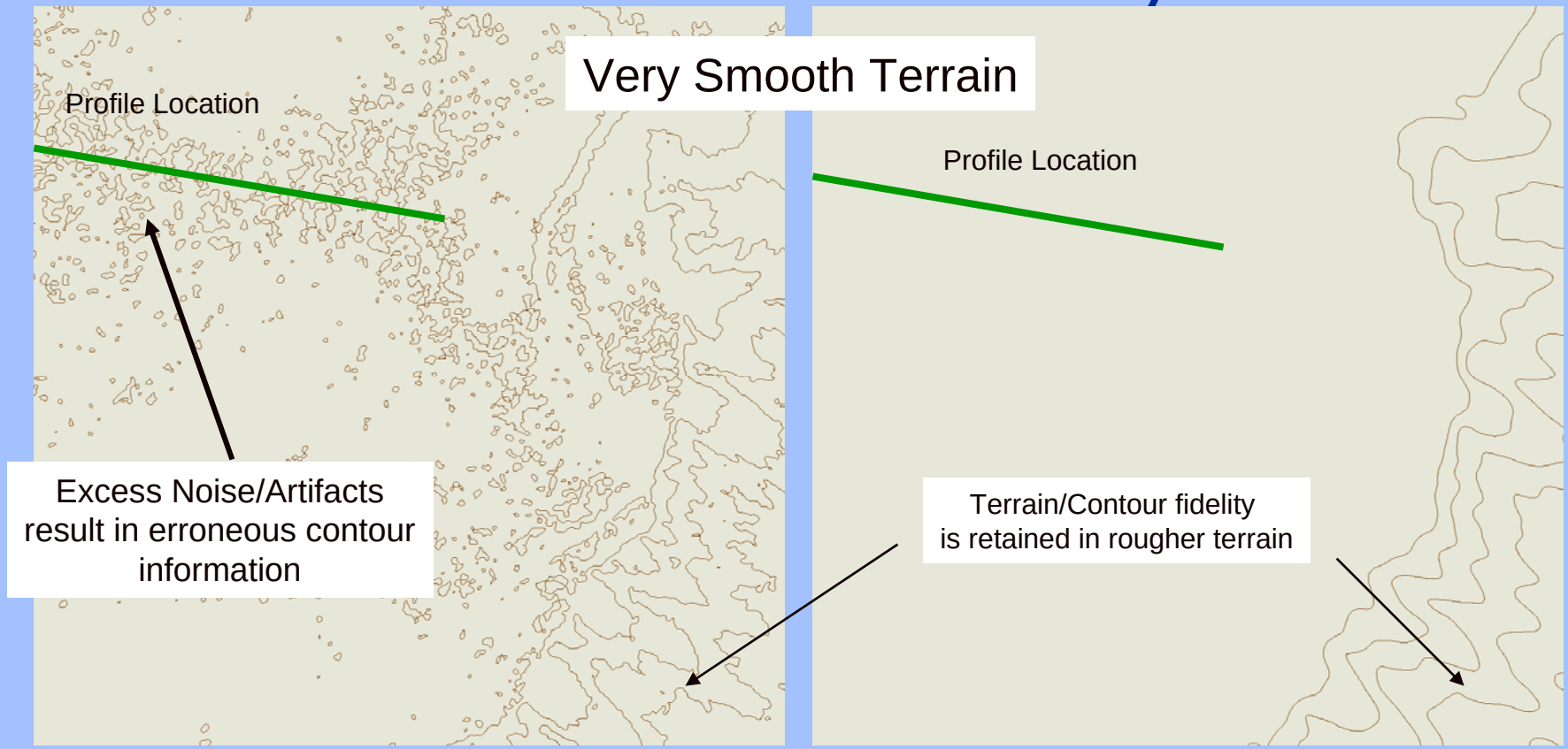
Yuma 20m Contours from DTED2



Yuma 20m Contours from filtered SRTM2
(3x3 Mean Filter/2 Passes)

Greatly Reduced Artifacts in the SRTM2 Filtered Contours

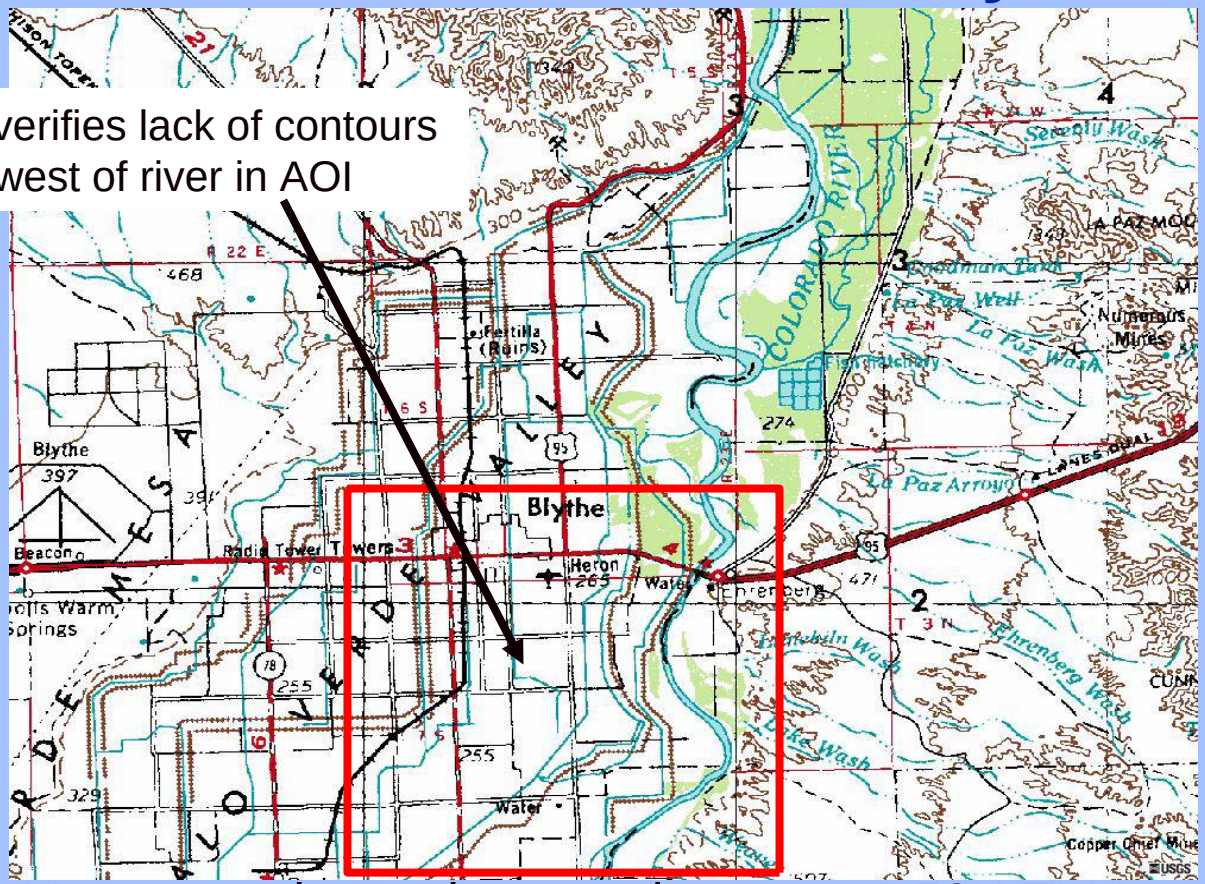
Noise Reduction Analysis



Blythe 20m contours from SRTM2
(No filter applied)

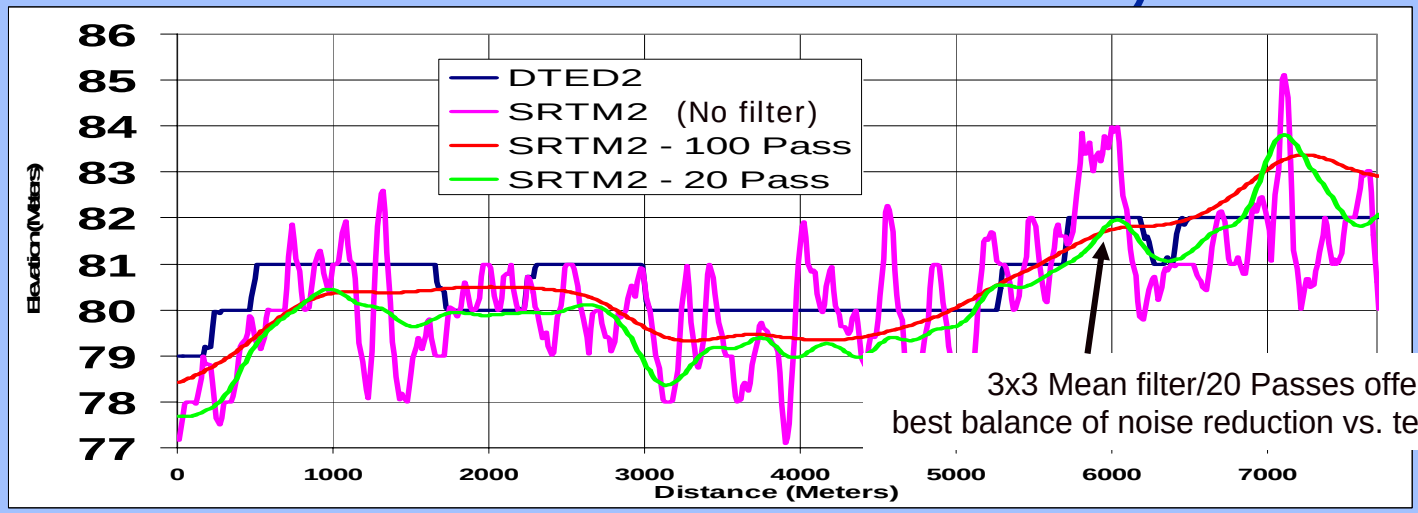
Blythe 20m contours from SRTM2
(3x3 Mean filter/20 passes)

Noise Reduction Analysis

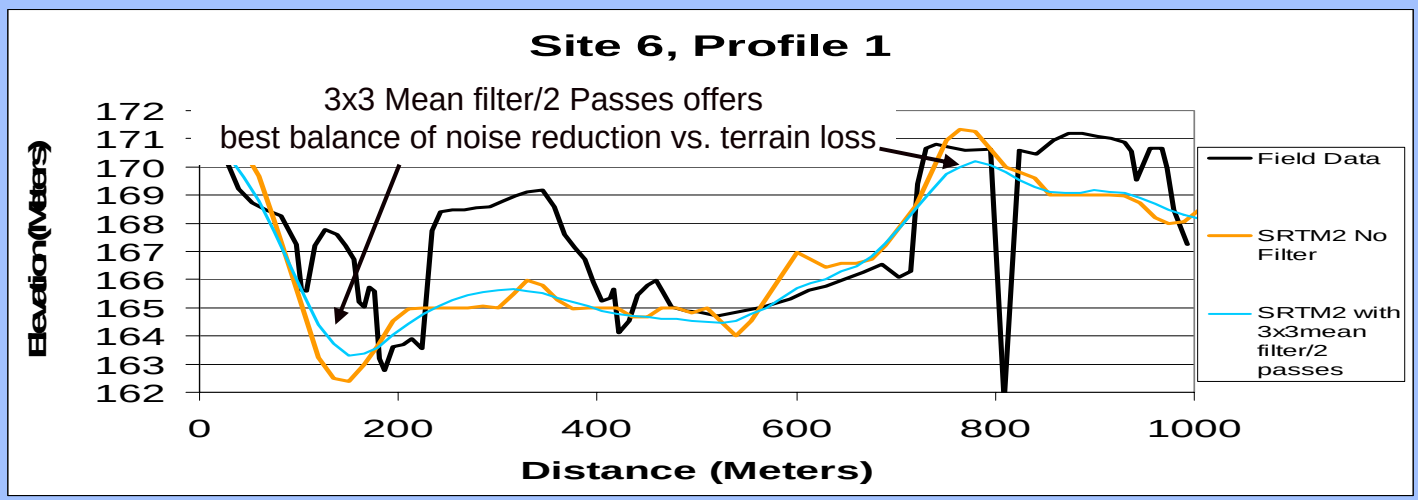


Very smooth terrain area shown on 1:50K TLM

Noise Reduction Analysis



Very Smooth Terrain



Moderate to Rough Terrain

Terrain Profiles

Noise Reduction Analysis

Conclusions

- Appreciable residual radar noise can be removed from SRTM2 but caution must be exercised to balance noise reduction with terrain loss.
- In moderate to rough terrain, a simple 3x3 mean filter @ 2 passes will improve SRTM2 performance enough to adequately support particularly "noise sensitive" applications such as LOS and contour generation.
- In very smooth terrain, a 3x3 mean filter @ 20 passes is optimal.
- These filter/pass and terrain roughness combinations provide the best balance between SRTM2 residual radar noise reduction and acceptable terrain loss….BUT…

**** There is NO SINGLE SOLUTION that can be generally applied to the SRTM2 data over the full range of terrain roughness conditions****

Follow-on Analysis
Preliminary Recommendations

- SRTM2 data in vegetated areas should be used with caution. Users should be educated about possible erroneous analysis resulting from misrepresentations of elevations under canopies.
- NGA should initiate additional filtering of SRTM2 data using a 3x3 low pass mean filter (variable: 2/20 passes depending on terrain roughness).
- In cases where currently available (unfiltered) SRTM2 must be utilized, users should be educated about how to reduce residual radar noise for their applications.

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